

Fast spectral variations of OBA stars

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Abstract. The present work is stimulated by the recent detection of the moderate line profile variations of selected lines on a time scale of minutes in FORS 2 spectra of the A0 supergiant HD 92207 (Hubrig et al. 2014). Recently, we investigated the variability of line profiles of selected OBA stars with the multi-mode focal reducer SCORPIO at the 6-meter BTA telescope. We discovered regular variations of H and He lines in the spectra of the O-type star HD 93521 (O9.5III) with periods 4-5 and 32-36 minutes. The possible origin of short time-scale spectral variations is discussed.

1. Introduction

Line profiles in spectra of OBA stars are varying on time scales from days to hours (Kaper et al. 1997; Dushin et al. 2013). The variable bright A0 supergiant HD 92207 has been monitored spectroscopically by Kaufer et al. (1997). The authors revealed the presence of non-radial pulsations (NRPs) in this star with a period of 27 days. The short time-scale line profile changes in the spectra of HD 92207 were detected by Hubrig et al. (2014), see also (Hubrig et al. 2015; Kholtygin et al. 2015). The authors detected the clearly visible LPVs belonging to different elements in individual subexposures reaching up to 3% in intensities and up to 30 km/s in radial velocities. Such short-term periodicity was not known before for non-radially pulsating supergiants and its study is crucial for modeling the stellar evolution.

To test whether short-periodic spectral variations are wide dispersed among OBA stars, we investigated the variability of line profiles of selected OBA stars with the multi-mode focal reducer SCORPIO at the 6-meter BTA telescope. In this paper we present the results of our search for the fast LPVs in the spectra of the O-type star HD 93521 (O9.5III).

2. HD 93521: line profile variations

The spectral observations of the fast rotating star HD 93521 ($V \sin i = 390$ km/s, (Rauw et al. 2008)) were carried out in 2015 Jan 19–20 with a multi-mode focal reducer SCOR-

PIO mounted in the prime focus of the 6-meter telescope BTA. The SCORPIO is usually used for observations of star-like and extended objects (Afanasiev & Moiseev 2005) in integral light with a low spectral resolving power. Our observations were made with a slit width of $0.5''$ in the spectral range $\lambda\lambda 4040 - 5850$ with the 3 s exposure. The spectral resolving power of $R \sim 2000$ and the signal to noise ratio $S/N \sim 2000$.

The total time of observations was $T_{\text{full}} = 76$ minutes. The number of obtained spectra was 529, one of them appeared to be a bad quality, so that finally 528 SCORPIO spectra were used. The reduction of the SCORPIO spectra was done with the MIDAS package using the standard procedures. All spectra were normalized to the continuum level using the approach by Kholtygin et al. (2006).

All analyzed lines in the SCORPIO spectra appeared to be variable. In Fig. 1 we plot the LPVs for H_δ and H_γ lines.

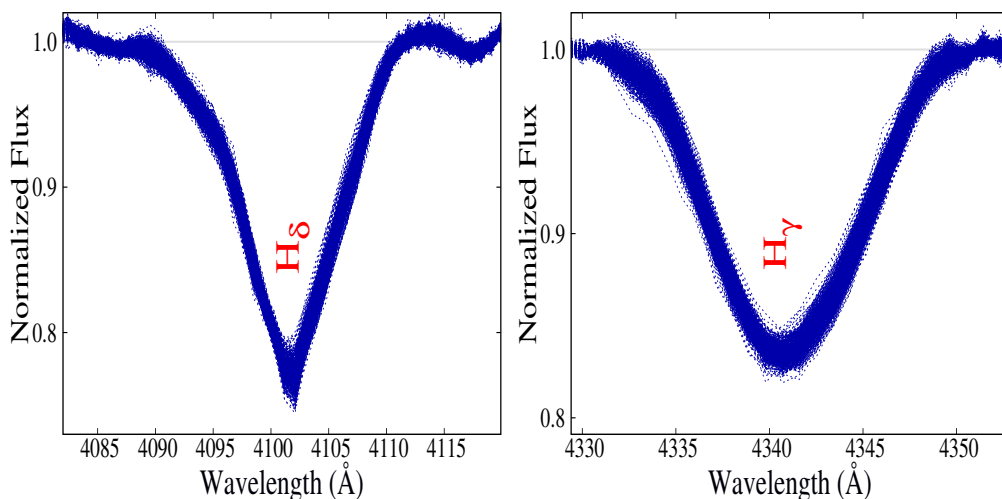


Figure 1. The overplotted H_δ and H_γ line profiles in the SCORPIO spectra of HD 93521.

As it clearly seen in Fig. 2, the line profiles of H and HeII lines change regularly.

3. HD 93521: Fourier spectra

The frequencies and periods of the LPVs were calculated using the CLEAN algorithm (Roberts et al. 1987) with modification by Vityazev (1996). The Fourier spectra of LPVs for H and HeII lines are presented in Fig. 3.

In Fig. 3 one can separate three groups of the regular components in the Fourier spectra: $\nu_1 = 0.21 - 0.26 \text{ m}^{-1}$ ($P_1 = 4 - 5 \text{ min}$), $\nu_2 = 0.028 - 0.030 \text{ m}^{-1}$ ($P_2 = 32 - 36 \text{ min}$), and $\nu_3 \approx 0.0092 \text{ m}^{-1}$ ($P_3 \approx 108 \text{ min}$).

The third component $P_3 > T_{\text{full}}$. In this case, we can not decide whether this component is real. However as it was shown by Kholtygin et al. (2007) even in this case such not very reliable component can be close to the real harmonic of the Fourier spectra if its period only slightly exceed the full length of the time series.

Rauw et al. (2008) detected two regular components of HeI and H_α LPVs in the spectra of HD 93521 with periods of 1.75 and 2.89 h. The authors identified these

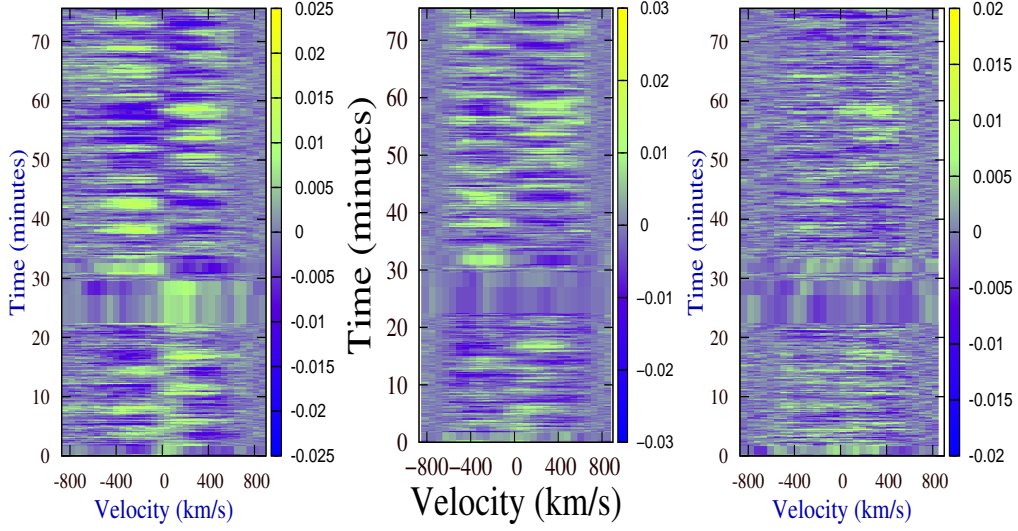


Figure 2. The dynamical spectra of H_β , H_γ and $\text{HeII } \lambda 4686 \text{ \AA}$ line profiles for HD 93521.

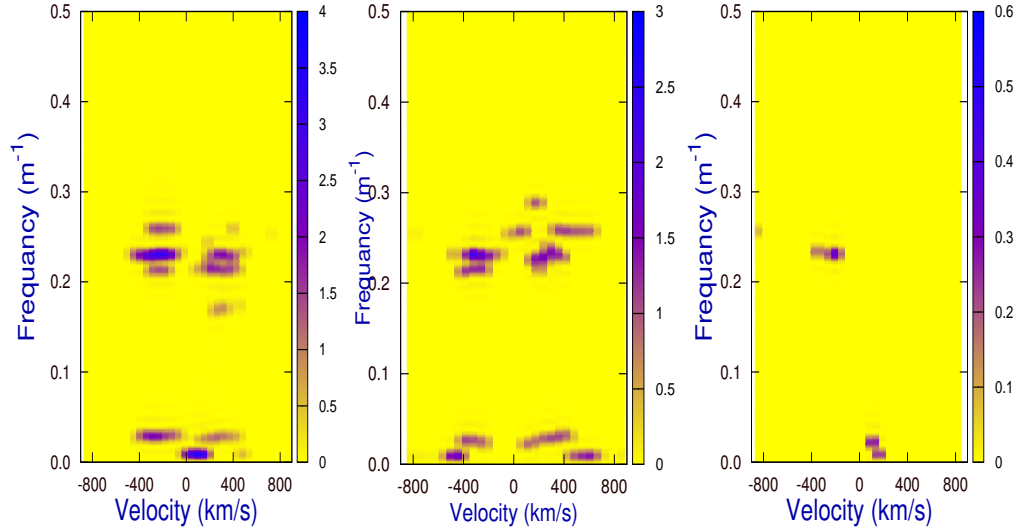


Figure 3. The Cleaned Fourier spectra for H_β , H_γ and $\text{HeII } \lambda 4686 \text{ \AA}$ line profiles in spectra HD 93521.

components as NRP $l = 8 \pm 1$ and $l = 4 \pm 1$ modes, respectively. Importantly, the shortest period $P=1.75 \text{ h}$ (105 min) is very close to our component P_3 . We suggest that our components P_1 and P_2 also can be assigned to NRP modes $l \sim 25$ and $l \sim 180$, accordingly.

4. Discussion and conclusion

The massive OBA stars are considered as type II supernova progenitors. A careful study of their variability provides important diagnostic means for internal and external (atmospheric) structure. Our recent search (Hubrig et al. 2014) for magnetic fields in selected OBA stars using FOcal Reducer low dispersion Spectrographs FORS 1 and FORS 2 in spectropolarimetric mode revealed the presence of strong line profile variations (LPV) in spectra of magnetic OBA stars.

Simple estimations by Kholtygin et al. (2015) show that the LPVs of such an amplitude as was detected for HD 92207 can be connected with the huge spots with diameter about of $40 R_{\odot}$ or with the large prominences with the mean size about a few solar radii. Regular LPVs in spectra of HD 93521 are variable on the time scales of 4-5 and 32-36 minutes can be connected with the high mode of NPPs. The connection of these LPVs with possible magnetic field of the star is under question.

The number of our spectropolarimetric observations of HD 92207 with the minutes time resolution (Hubrig et al. 2014) is too small to find the regular component in the LPVs of this star. Therefore we can not exclude the possibility that LPVs in the spectrum of HD 92207 are also associated with high modes of non-radial pulsations like the 5-minute solar oscillations (see, e.g. Marmolino & Severino (1989)).

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